Innovative Cardiac Devices on Chest Imaging
An Update

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Abstract: Over the past decade, a rapidly increasing number of new cardiac devices have been created. Remaining current with these devices and how they appear on chest radiographs and other modalities used in chest imaging can be a challenge for the interpreting radiologist. This review is provides a concise summary of various common cardiac devices as well as recently developed devices that will be increasing in frequency over the coming years.

Key Words: leadless pacemaker, subcutaneous ICD, atrial exclusion device, exclusion device, ECMO, TAVR, MitraClip

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EDUCATIONAL OBJECTIVES

After completing this CME activity, physicians should be better able to:

(1) Recognize several recently-introduced and increasingly used cardiac devices present on chest radiography and chest CT.
(2) Discuss why these devices are placed and how best to image them.
(3) Identify when these devices are malpositioned and common pitfalls.

An estimated 129 million chest radiographs were performed in the United States in the year 2006, which is the equivalent of 365,000 chest radiographs obtained per day.[1] Given that the patient population is increasing yearly along with an estimated 5.5% annual growth in the number of radiographs performed, this number is currently likely closer to half a million chest radiographs performed daily. A large number of these patients have temporary or permanent support equipment present on their radiographs. It is important for the interpreting radiologist to be familiar with all devices present on the radiograph in order to accurately detect malposition or complication as a result of the device. With the exponentially increasing number of innovative cardiac devices, particularly minimally invasive devices for cardiomyopathies and valvular disease, it can be difficult for radiologists to remain current with these devices and their appearance on chest imaging.

The purpose of this review is to familiarize the reader with these innovative devices, their proper position on radiographs, and common associated pitfalls. Specifically, we will discuss cardiac conduction devices (CCDs), cardiac assist devices (both temporary and permanent), extracorporeal membrane oxygenation (ECMO) support devices, transcatheter valves and valve repair devices, implanted cardiac monitors, and left atrial exclusion devices.

PACEMAKERS AND IMPLANTABLE CARDIOVERTERS-DEFIBRILLATORS (ICDs)

Chest radiographs are frequently obtained for evaluation of CCDs (pacemakers and ICDs), as this is the only modality that can clearly assess lead integrity and position. Transvenous CCDs are currently the most commonly inserted; however, recently introduced devices include an entirely intracardiac leadless pacemaker and a totally subcutaneous ICD, which will be seen with increasing frequency on chest radiographs.

Permanent pacemakers are most commonly placed for the treatment of symptomatic bradycardia and heart block, and temporary pacemakers are often inserted following cardiac surgery/percutaneous intervention (Fig. 1) or as a bridge to a permanent pacemaker. They are most commonly placed using a right internal jugular approach or a left subclavian approach, as this offers the most direct access to

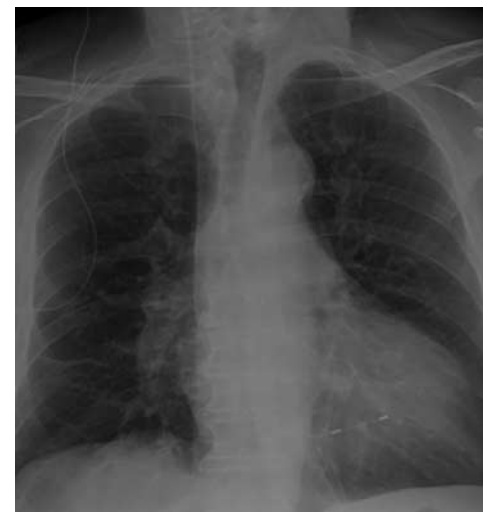

FIGURE 1. Temporary single-lead transvenous pacemaker: frontal radiograph depicting temporary right internal jugular pacemaker with tip in the RV.

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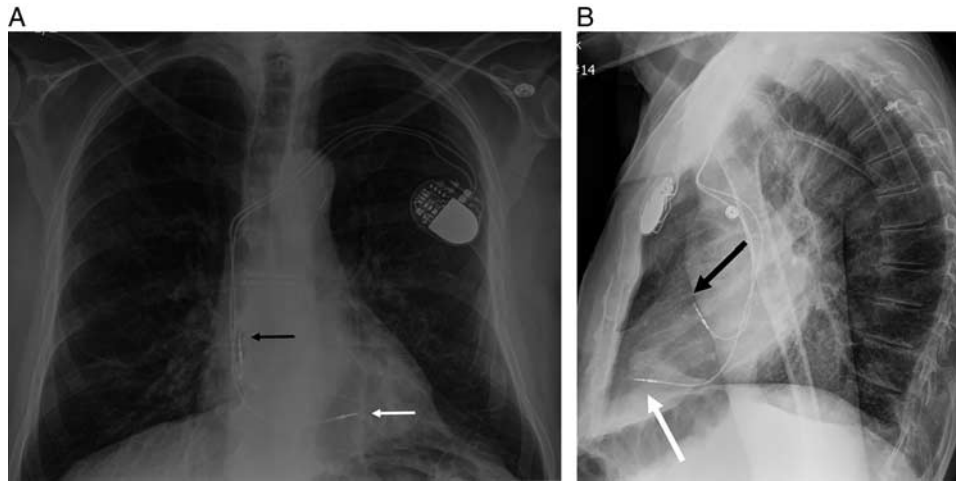

FIGURE 2. Permanent dual-lead transvenous pacemaker: frontal (A) and lateral (B) radiograph depicting dual-lead pacemaker with lead tips in the right atrial appendage (black arrow) and right ventricular apex (white arrow).

the superior vena cava (SVC) without a sharp turn. Depending on the reason for insertion, a specific type of transvenous pacemaker is placed: single chamber (right ventricular apex lead), dual chamber (right atrial appendage and right ventricular apex leads), and biventricular (leads in the right ventricular apex and coronary sinus with a possible additional lead in the right atrial appendage) (Fig. 2). The coronary sinus lead is placed via the right atrium (RA) into the coronary sinus and terminates in a posterior/lateral cardiac vein adjacent to the lateral left ventricular (LV) wall. In addition to the leads, the second component of all permanent CCDs is the pulse generator.[2]

ICDs are placed in patients at high risk for life-threatening ventricular arrhythmias such as those with severe cardiomyopathy, history of sudden cardiac arrest, or other known conduction disturbances. Typically, the device consists of a single lead with 2 shock coils with one coil terminating at the brachiocephalic vein-SVC junction and the second coil in the right ventricle (RV). ICD leads can be distinguished from pacemaker leads by the presence of a radiopaque insulation over a section of the lead, which is the site where the shock is delivered from an ICD lead.

Pacemakers and ICDs can also be combined into one device in a variety of methods. Cardiac resynchronization therapy, which is used for patients with congestive heart failure, is the specific combination of a biventricular pacemaker and ICD in which the pacemaker leads are present in the RA and coronary sinus and the pacemaker-ICD lead is in the RV (Fig. 3). When evaluating CCDs on chest radiographs, it is important to exclude abnormal lead positioning, presence of lead fracture, and disengagement of the lead from the generator[2] (Figs. 4, 5). A 2-view radiograph (frontal and lateral) is necessary to assess proper positioning, as aberrant placement may be obscured on a frontal view radiograph only

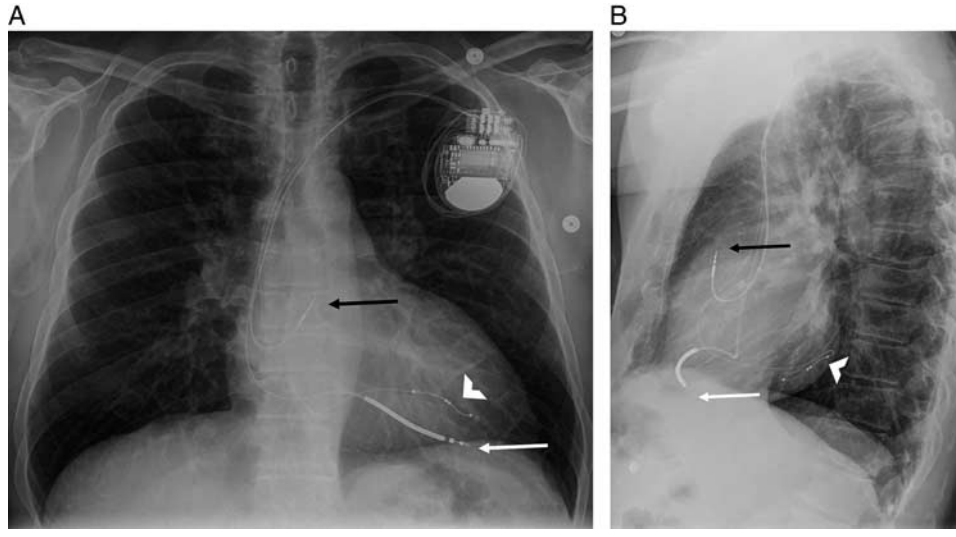

FIGURE 3. Permanent transvenous biventricular automatic ICD: frontal (A) and lateral (B) radiograph depicting biventricular automatic ICD/pacemaker with leads in the right atrial appendage (black arrow), RV (white arrow), and coronary sinus (white arrowhead). Note that the coronary sinus lead courses leftward on the frontal, but posterior on the lateral view.

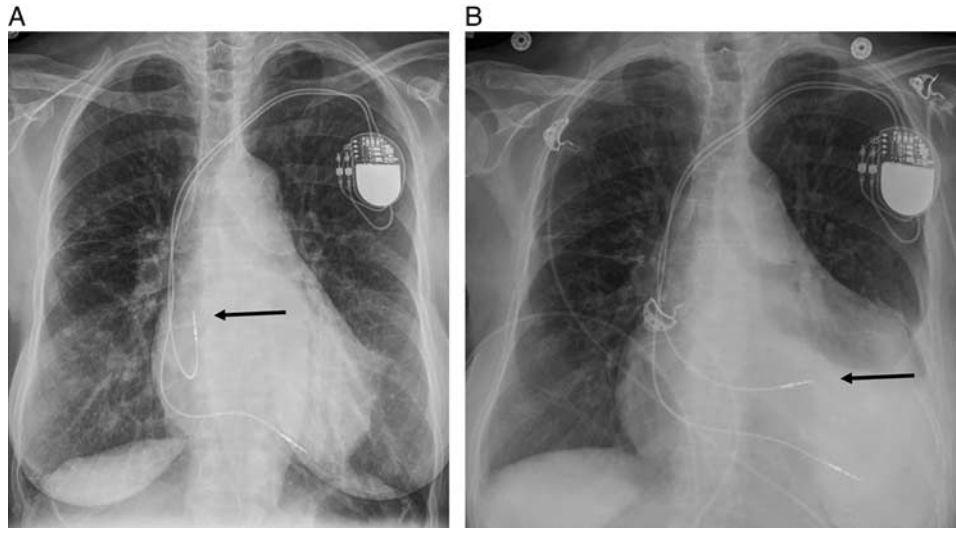

FIGURE 4. Perforated pacemaker lead: initial (A) and follow-up (B) radiograph of dual-lead pacemaker. Note the dislodged atrial lead (black arrow) and the enlarged cardiac silhouette on follow-up radiograph, consistent with myocardial perforation and resultant hemopericardium.

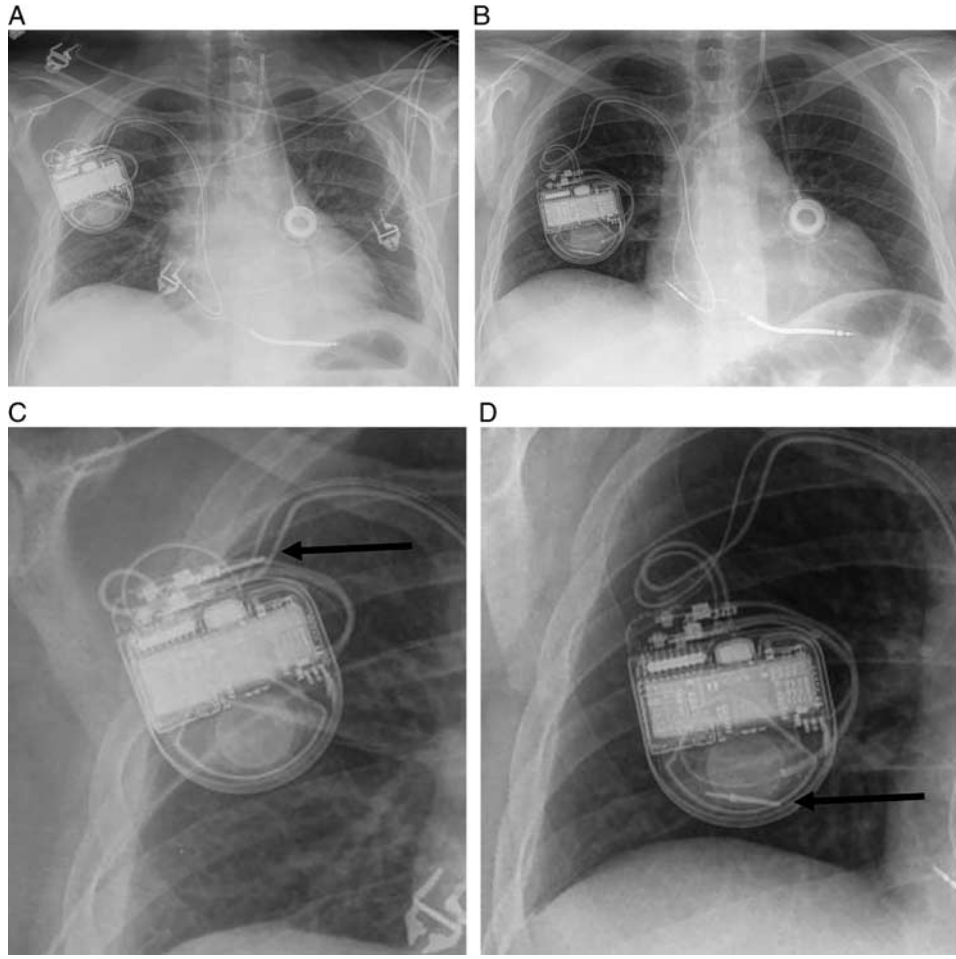

FIGURE 5. Pacemaker malfunction due to dropped pin: initial (A) and follow-up (B) radiograph in patient with new "ECG abnormalities" depicting dropped insolating pin (black arrow) into the generator pocket (see initial [C] and follow-up [D] magnification).

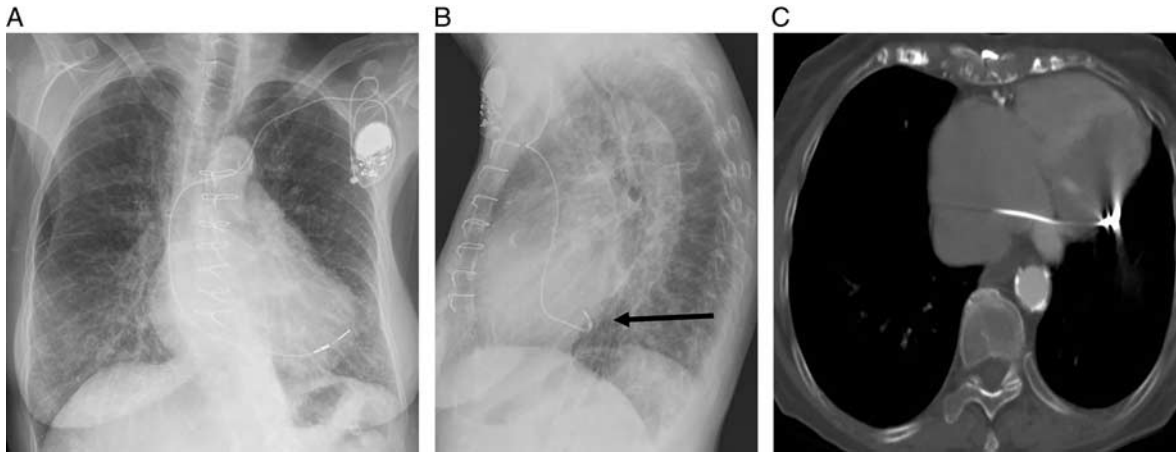

FIGURE 6. Perforated pacemaker lead: frontal (A) and lateral (B) radiograph as well as an axial CT image (C) depicting a perforated pacemaker lead (black arrow) coursing via the coronary sinus into the left lateral pericardial space.

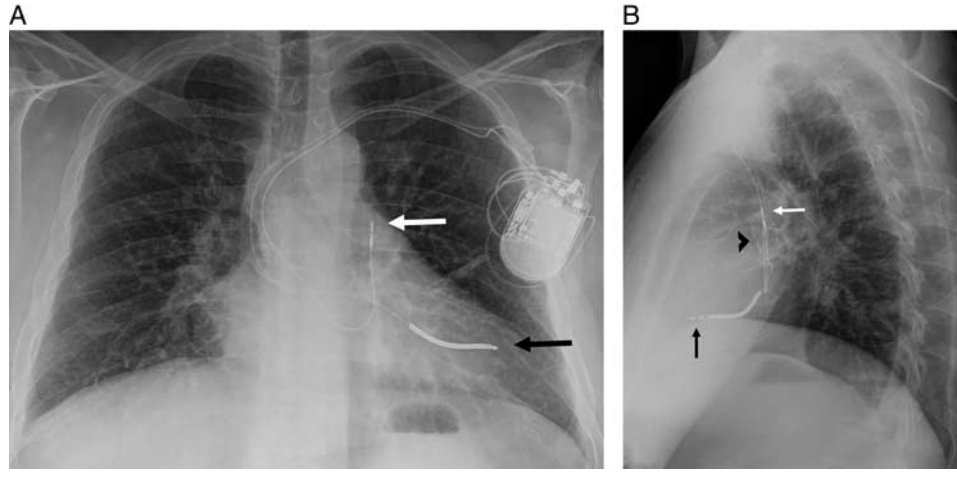

FIGURE 7. Pacemaker in patient with repaired transposition of the great arteries: frontal (A) and lateral (B) radiograph of dual-lead ICD after Mustard repair. Note the left atrial (white arrow) and LV (black arrow) lead coursing through the stented Mustard baffle (black arrowhead).

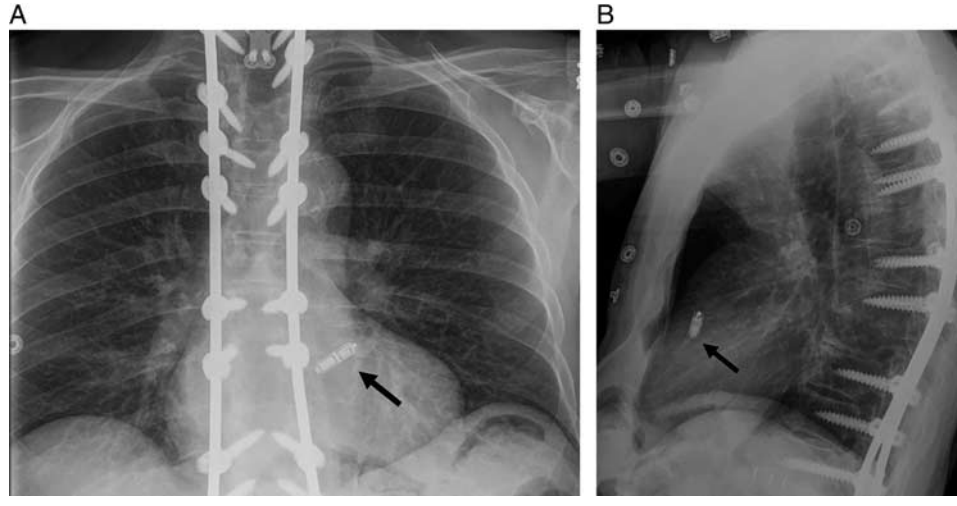

FIGURE 8. Micra intracardiac pacemaker: frontal (A) and lateral (B) radiograph of Micra intracardiac pacemaker, which appears similar to a USB drive. The patient also has thoracolumbar posterior spinal fusion hardware. Attention must be focused on positioning during image acquisition to visualize the device on both views with adequate patient rotation.

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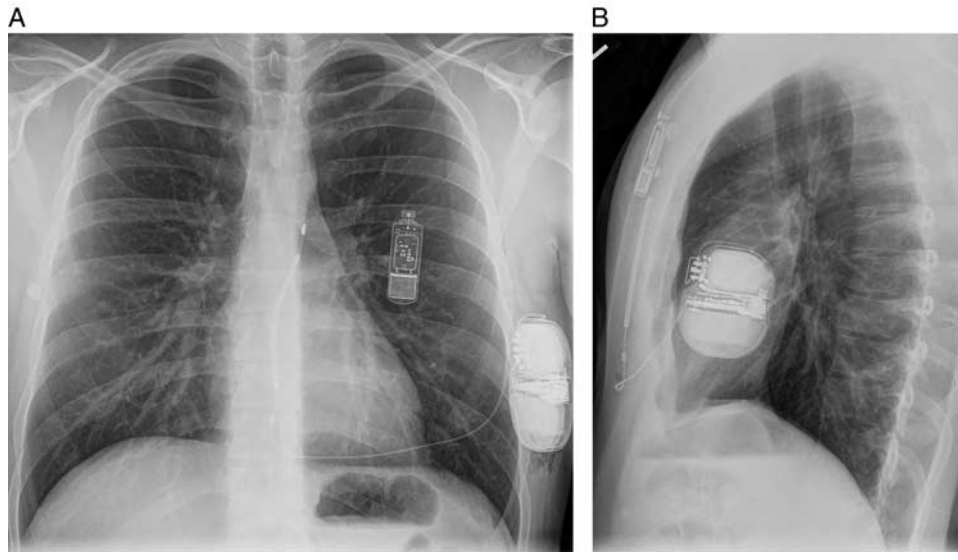

FIGURE 9. Subcutaneous parasternal ICD: frontal (A) and lateral (B) radiograph of subcutaneous ICD. Note the vertically oriented parasternal electrode and the horizontally oriented wire creating a perfect 45 degrees cardiac vector. In addition, an ILR is present, seen in the subcutaneous soft tissues on the lateral view.

(Fig. 6). Knowledge of any underlying congenital heart disease in the patient is also important, as pacemakers/ICDs may be placed in patients with repaired transposition of the great arteries, resulting in unusual lead configuration (Fig. 7).

An emerging therapy is a self-contained leadless cardiac pacemaker (Micra Transcatheter Pacemaker System, Medtronic and Nanostim LP, St. Jude Medical), which is deployed through the femoral vein and directly implanted into the RV[3,4] (Fig. 8). By eliminating the presence of leads and the device pocket, there will likely be a decreased risk of both short-term and long-term complications including infection, venous occlusion due to scarring, and thromboembolism across a patent foramen ovale. Complications include device dislodgment and cardiac perforation.

An additional novel therapy is the entirely subcutaneous ICD (Cameron Health, San Clemente, CA). In this system, the pulse generator is located in the subcutaneous tissues over the sixth rib between the midaxillary and anterior axillary line.[5] This is connected to a sensing electrode, which is composed of an 8 cm shocking coil flanked by 2 sensing electrodes, which are all located parallel to and within 1 to 2 cm left of the midsternum (Fig. 9). It is important to evaluate for appropriate parasternal device location, as inappropriate placement or migration may not allow for adequate cardiac defibrillation when needed. Deviation of the vertically positioned coil may cause device malfunction (Fig. 10), as the vector between the horizontally oriented lead and the vertically oriented coil determines the shock axis.[6] A major disadvantage at present is that this device is unable to provide cardiac pacing.[7]

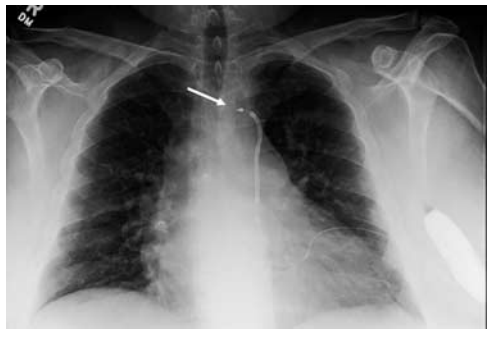

FIGURE 10. Malpositioned subcutaneous ICD: frontal radiograph of subcutaneous ICD. Note the rightward deviation of the distal tip (white arrow), interfering with ICD functionality.

VENTRICULAR ASSIST DEVICES (VADs)

VADs are used in patients with ventricular dysfunction (left, right, or biventricular) and can be temporary or permanent depending on the indication for placement and the type of device used. Temporary percutaneous devices are

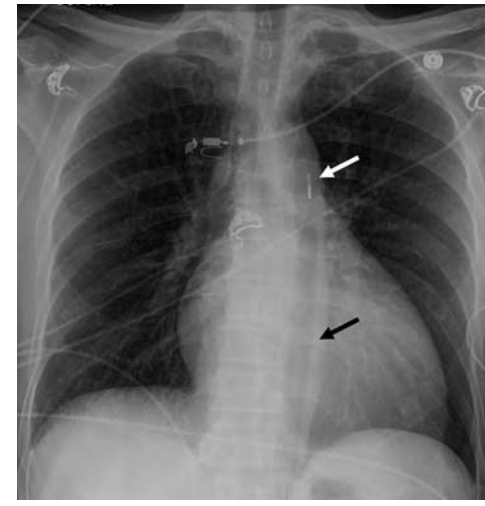

FIGURE 11. IABP: frontal radiograph depicting inflated IABP. Note the tip marker just below the aortic arch (white arrow), distal to the left subclavian artery take off. The inflated balloon (black arrow) is incidentally visualized.

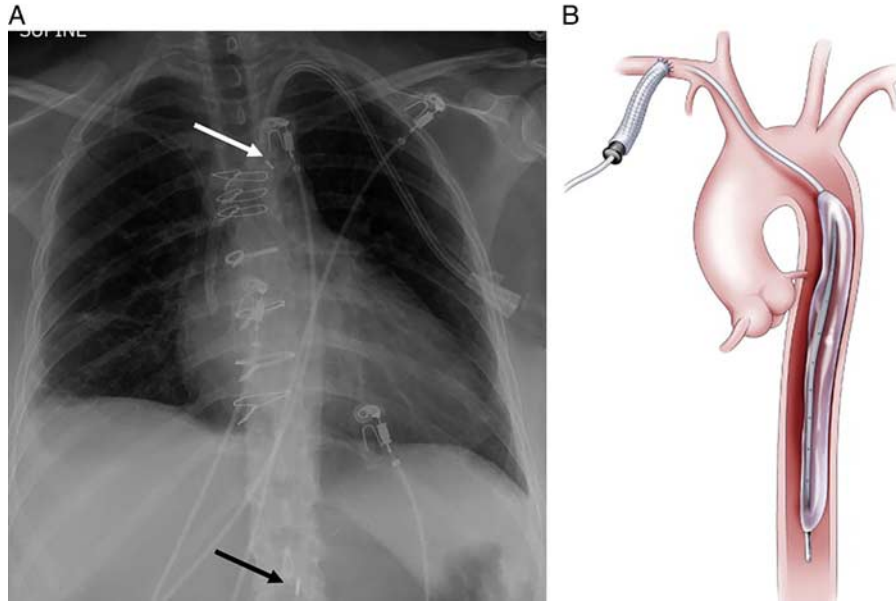

FIGURE 12. Right subclavian artery approach IABP. A, Frontal radiograph depicting right subclavian artery approach IABP. Note the smaller comma-shaped marker (white arrow) is just below the aortic arch, whereas the larger marker is below the diaphragm (black arrow), because of inverse placement. B, Subclavian IABP (used with permission).

commonly used in cardiac intensive care units in patients with acute decompensated heart failure and include the intra-aortic balloon pump (IABP), the Impella (Abiomed Inc., Danvers, MA) VAD, and the TandemHeart plus Protek-Duo (CardiacAssist Inc., Pittsburgh, PA) VAD.[8] Temporary devices (both percutaneous and surgically implanted) are used as a bridge to cardiac transplantation or as a bridge to myocardial recovery. Permanent devices are utilized for these indications as well as for long-term destination therapy in patients with irrecoverable myocardial function who are not candidates for cardiac transplant.

An IABP is a counter-pulsation device used in patients for a variety of reasons including cardiogenic shock, prophylactic support before cardiac surgery, patients weaning from cardiopulmonary bypass or with postsurgical myocardial dysfunction/low cardiac output syndrome, or as a mechanical bridge to other cardiac assist devices. It consists of a balloon that spans the length of the thoracic descending aorta (22 to 27.5 cm in length and 15 to 18 mm in diameter once inflated), which is sized on the basis of the patient's height (Fig. 11). The balloon is placed into the descending aorta via access through the femoral artery. The balloon inflates with Helium during diastole, which increases coronary artery perfusion and deflates just before systole, resulting in sudden afterload reduction, increased stroke volume, and cardiac output. Assessment of proper positioning is paramount to prevent major complications. Ideally, the tip should be located 1 to 2 cm distal to the left subclavian artery origin and extend distally to the origin of the celiac artery. It should not be placed too distal so as to obstruct the renal artery inflow.

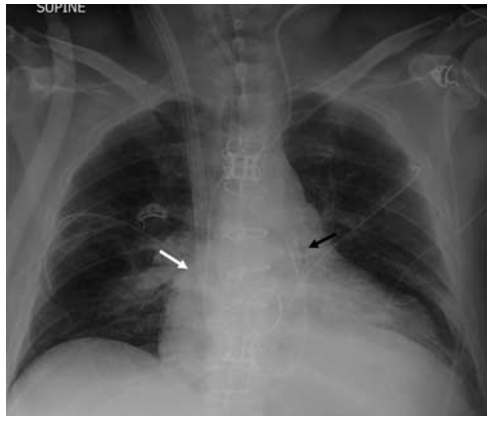

FIGURE 13. RVAD: frontal radiograph depicting right internal jugular approach of RVAD with Protek Duo dual-lumen cannula. The distal tip of the cannula is in the main PA (black arrow), the proximal outlet in the RA (white arrow).

A tip that is located below T5-6 or >5 cm distal to the aortic arch has been shown to be predictive of major complications.[9] Similarly, a balloon that is placed too proximal can obstruct the subclavian or carotid arteries, leading to devastating consequences. The balloon itself is radiolucent but marked with a radiopaque tip both proximally and distally.

Absolute contraindications to IABP placement are aortic dissection and aortic valve insufficiency. Relative contraindications include abdominal aortic aneurysm, thrombocytopenia, and severe atherosclerosis.[10] The balloon is designed to be approximately 85% to 90% occlusive. Total occlusion would result in possible aortic wall trauma and damage to both red and white blood cells.

A novel approach has been described in which the IABP is placed via the right subclavian artery,[11] which removes bed rest precautions and reduces leg ischemia rates, reportedly ranging between 5% and 19%.[10] When an IABP is placed from the lower extremity, a large radiopaque marker is present near the aortic arch, and a small radiopaque marker is present at the level of the celiac axis.

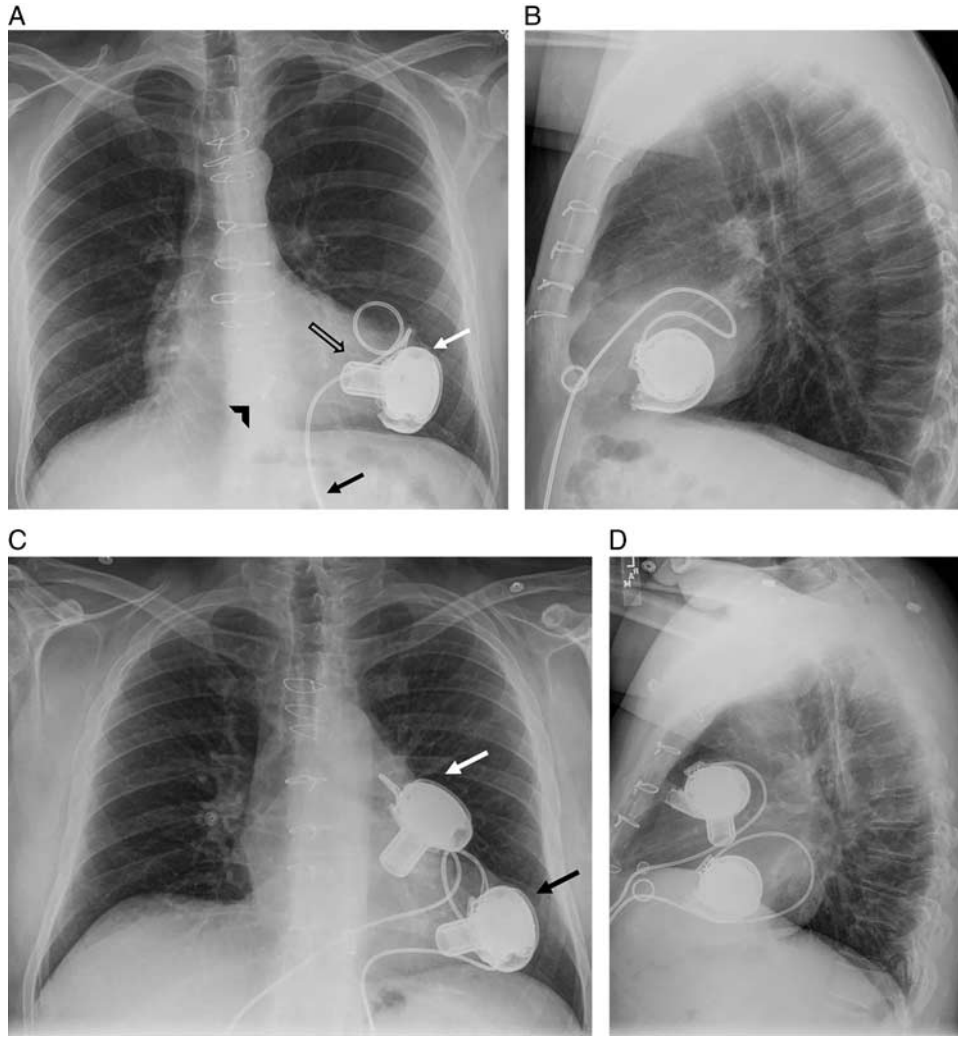

FIGURE 14. HeartWare LVAD: frontal (A) and lateral (B) radiograph depicting HeartWare LVAD. The entire pump apparatus (white arrow) is within the pericardial sac. The LV cannula is pointed toward the mitral valve (open black arrow). The outflow cannula to the ascending aorta is radiolucent (black arrowhead). The driveline (black arrow) extends beyond the field of view. Frontal (C) and lateral (D) radiograph depicting HeartWare LVAD (black arrow) and RVAD (white arrow).

Reverse placement of the IABP (eg, transsubclavian approach) results in the smaller marker being present near the aortic arch and the larger marker at the level of the celiac axis (Fig. 12).

The Impella RP and TandemHeart devices are both percutaneously placed and function as temporary right ventricular assist devices (RVADs). The Impella RP is a 9 Fr catheter that is placed through the femoral vein with the proximal tip terminating in the inferior vena cava (IVC) and the distal tip in the pulmonary artery (PA). Blood enters the inlet valve in the IVC and exits through the outlet valve in the PA, allowing for bypass of the right heart for up to 14 days. The TandemHeart VAD in combination with the Protek-Duo cannula functions similarly but with the added benefit of an external pump (instead of passive bypass) and is approved for use up to 30 days.[12] A single catheter is placed with an inflow valve located in the RA and an outflow valve located in the PA (Fig. 13).

Surgically placed RVADs include the CentriMag RVAS (Thoratec Corp., Pleasanton, CA) and HVAD system (Heartware, Framingham, MA). The CentriMag RVAS is a temporary device for use up to 30 days and consists of a pump, motor, an inflow cannula in the RA, and an outflow cannula in the PA. The Heartware HVAD system is a permanent VAD that can be used as either an RVAD or a left ventricular assist device (LVAD)[13] (Figs. 14C, D).

LVADs are used to bypass the left heart for patients with left heart failure. Since their implementation in 1984, significant advancements have been made such that the newest generation of LVADs are powered by an internal electric motor and blood is pumped centrifugally such that there is no contact between the blood and the rotor. For example, the third-generation Heartware LVAD (Heartware) (Fig. 14) and the third-generation Heartmate III (Thoratec Corp.) (Fig. 15) are both intrapericardial in location in which the pump is integrated with the inflow cannula; hence it is no longer necessary to create a separate pump pocket in the thorax. Second-generation LVADs are still commonly used, and hence it is important for the

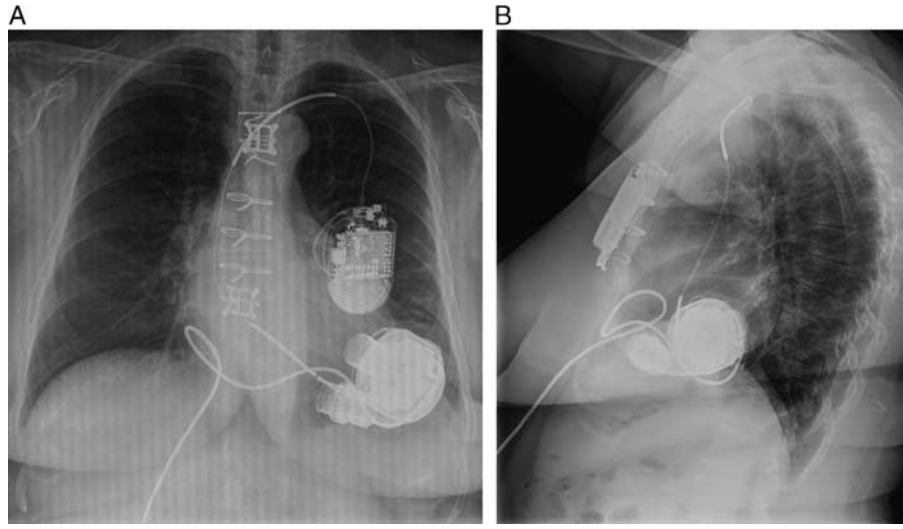

FIGURE 15. Third-generation Heartmate III LVAD: frontal (A) and lateral (B) radiograph depicting Heartmate III LVAD. The monoblock design enables an intrapericardial position with both inflow and outflow within 1 apparatus.

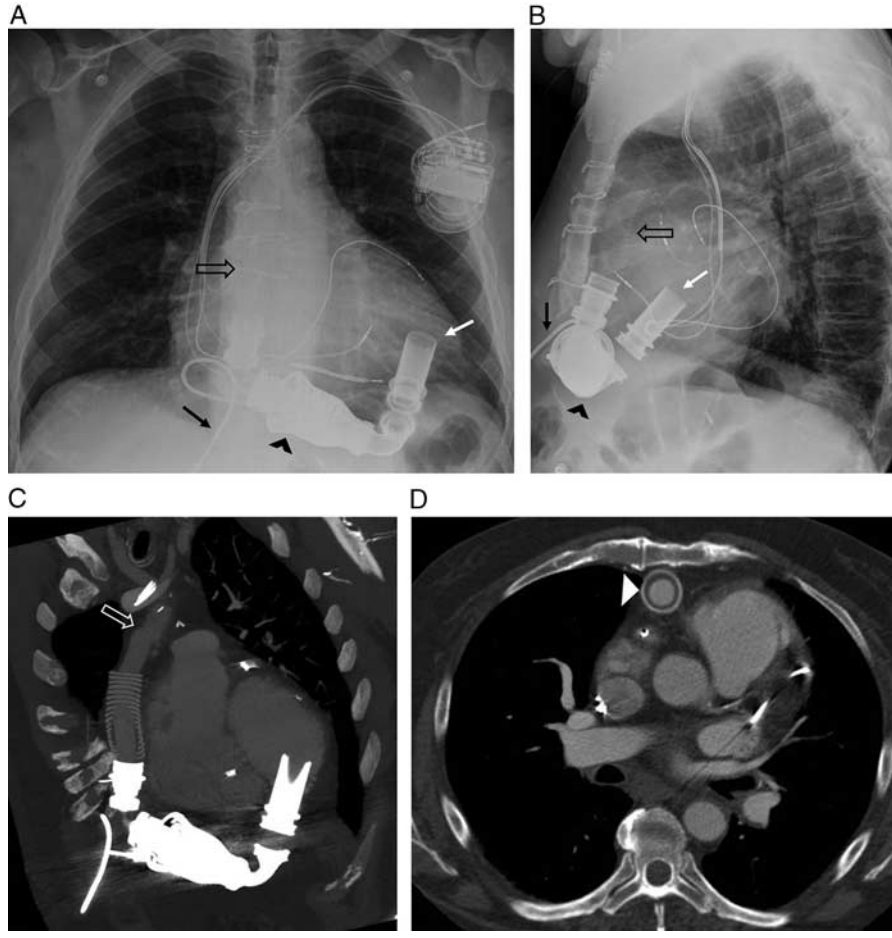

FIGURE 16. Second-generation HeartMate II LVAD: frontal (A) and lateral (B) radiograph, CT coronal MIP (C), and axial soft tissue window (D) depicting HeartMate II LVAD. The pump (black arrowhead) is in a preperitoneal pocket, because of the larger footprint. The LV cannula (white arrow) is well seated in the LV without myocardial tenting. The outflow cannula anastomoses to the distal ascending aorta (open white arrow). Close attention must be paid to the outflow-aorta anastomosis; kinks and/or stenosis impairs LVAD function. Note hypodense ring in outflow cannula consistent with the outflow cannula (white arrowhead) surrounded by a protective layer. The driveline (black arrow) is partially visualized.

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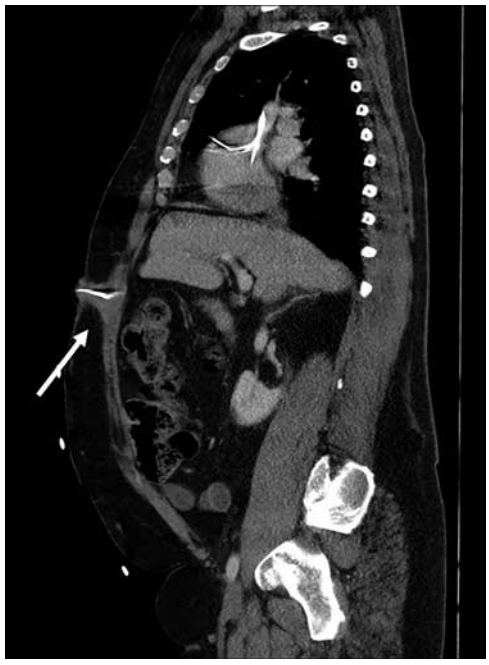

FIGURE 17. Driveline infection in patient with LVAD: sagittal MIP depicting driveline with increasing surrounding enhancing soft tissue (white arrow) in the setting of driveline infection.

radiologist to also be familiar with these devices[14] (Fig. 16). The inflow cannula inserts directly into the LV apex and blood is returned to the body via the outflow cannula located in the ascending aorta. The appearance of the outflow cannula on contrast-enhanced computed tomography (CT) may mimic a circular thrombus because of the dual-lumen construction (outflow cannula surrounded by protective layer)[15] (Fig. 16D). The pump is powered by the driveline, which exits the body through the abdomen, and can serve as an entry site for bacteria (Fig. 16A). The primary differences are that in second-generation LVADs, the pump is usually in a separate location within a preperitoneal pocket, the blood is circulated via a rotary pump that directly contacts the blood, and the overall design is larger. First-generation LVADs, which function by pulsatile flow rather than continuous flow, are no longer routinely used in the United States.

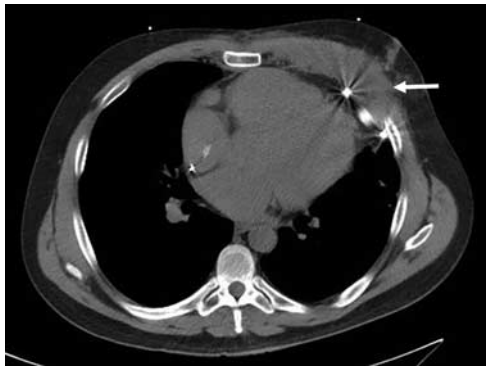

FIGURE 18. Complication after LAVD-hematoma: axial CT image depicting pectoralis hematoma after LVAD (white arrow).

It is important to ensure that the inflow cannula located at the LV apex is directed toward the mitral valve and that there are no kinks in the outflow cannula. Common complications of LVAD placement include infection (evaluate the pump pocket and image the driveline exit site on CT) (Fig. 17), hemorrhage (evaluate the pericardium for effusion) (Fig. 18), and thrombus/embolus.[16]

The Impella is a temporary ($\leq$6 h) or short-term ($\leq$4 d) LVAD indicated for use during high-risk percutaneous coronary interventions performed in hemodynamically stable patients with severe coronary artery disease, and for the treatment of ongoing cardiogenic shock that occurs immediately (<48 h) following acute myocardial infarction or open-heart surgery as a result of isolated LV failure. The 9 Fr catheter is inserted via arterial access (femoral, axillary, or direct aortic)[17] and positioned within the LV. The axial pump aspirates blood from the LV through an inlet area near the tip and expels blood from the catheter into the ascending aorta. The 2 radiopaque markers should be positioned above and below the aortic valve if placed appropriately. Ideally, the inlet should be placed ~3.5 cm below the aortic valve to avoid interference with the mitral valve apparatus[18] (Fig. 19).

ECMO

ECMO is a means of providing temporary cardiopulmonary support for patients in both cardiac and respiratory failure or in patients with severe respiratory failure alone that is not responsive to routine first-line therapies.[19] Although ECMO is not an innovative technique and has been routinely used for cardiopulmonary support in the pediatric intensive care unit, it is being increasingly used in adults after a study by Peek et al[20] demonstrated a potential benefit in transferring patients with severe ARDS to a center with ECMO capability. Therefore, it is important to understand the catheters present, their appropriate positions, and potential complications when this form of life support is utilized.

There are 2 types of ECMO circuits: (1) veno-arterial (VA), which is used to bypass both the heart and lungs, and (2) veno-venous (VV), which is used to bypass the lungs only. In VA-ECMO, blood is extracted through a venous catheter terminating in the SVC near the cavoatrial junction or in the femoral vein, oxygenated in the ECMO circuit, and returned to the systemic circulation via an arterial catheter (placed most commonly in the femoral artery, axillary artery, or right carotid artery) (Fig. 20). If the femoral artery catheter is too large, distal perfusion to the lower extremity may be compromised. Therefore, a distal perfusion catheter in the middescending thoracic aorta is occasionally placed to empirically prevent this complication.[21]

In VV-ECMO, blood is extracted through a venous catheter terminating in the SVC, oxygenated in the ECMO circuit, and is returned to the venous circulation either through the same vein via a dual-lumen catheter or separate SVC/cavoatrial junction cannula, or returned to a different vein (femoral vein) through a separate catheter (Fig. 21). Complications of ECMO include hemorrhage, pulmonary embolism, intracardiac thrombus, and limb ischemia.[22,23]

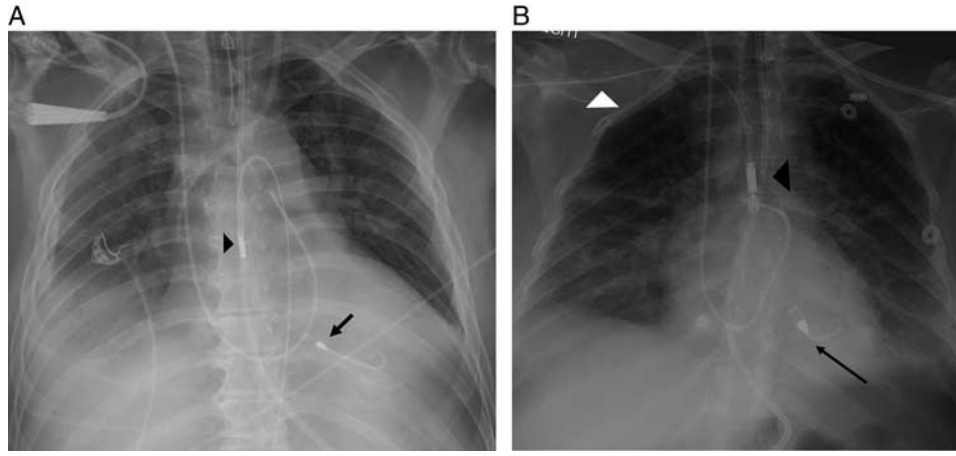

FIGURE 19. Temporary LVAD—Impella catheter: frontal radiographs depicting femoral (A) and right subclavian (white arrowhead) approach (B) Impella catheter with radiopaque marker above (black arrowhead) and below the level of the aortic valve (black arrow). The LV marker is the pump inflow, whereas the aortic marker represents the outflow.

TRANSCATHETER VALVES AND VALVE REPAIR

Transcatheter aortic valve replacement is an innovative technique in which the aortic valve is replaced percutaneously without the need for traditional median sternotomy and open-heart surgery. Most commonly, one of these access routes is used: transfemoral, transapical, transsubclavian, or direct aortic[24] via the chimney approach. More recently, Lederman et al described the emerging use of transcaval transcatheter aortic valve replacement in which the IVC is cannulated and used to access the aorta in patients with diseased iliofemoral arteries.[25]

Two aortic valves currently available for use are the CoreValve (Medtronic, Minneapolis, MN) (Fig. 22) and the Sapien 3 (Edwards Lifesciences, Irvine, CA) (Fig. 23). Both valves have bioprosthetic pericardial valve leaflets surrounded by a fenestrated metallic frame.[26] The Sapien 3 is a balloon-expandable valve composed of bovine pericardium valve leaflets surrounded by a cobalt chromium alloy frame and polyethylene terephthalate skirt. The CoreValve is a self-expandable valve composed of porcine pericardium valve leaflets surrounded by Nitinol mesh. Its shape resembles that of a goblet, whereas the Sapien 3 valve has a classic cylindrical stent shape. Additional models of the Edwards valve are also approved for mitral and pulmonic valve replacement (Fig. 24).

Both valves are available in several sizes and are easy to distinguish from surgically placed valves because of the metallic framework that is universally present in all percutaneously placed valves. Although the valves are easily seen on radiographs, CT can be used to evaluate stent position, valve geometry, and valve function.[27]

An emerging application for transcatheter heart valves is replacement for failed bioprosthetic surgical valves. The surgical valve is replaced within a percutaneously placed valve (valve-in-valve), which spares the

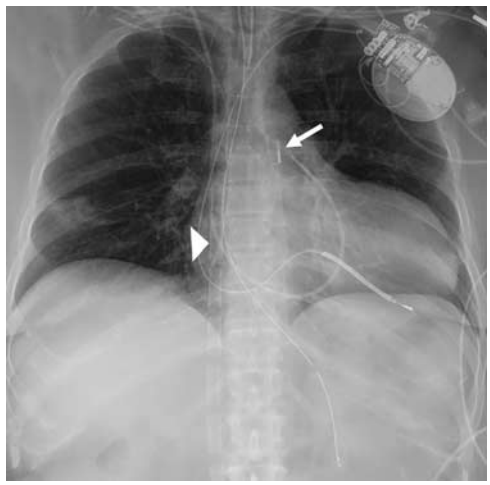

FIGURE 20. Veno-arterial (VA) ECMO: frontal radiograph in patient with VA-ECMO because of myocardial infarction. The venous cannula terminates in the RA (white arrowhead). The arterial line is in the right femoral artery, not depicted. IABP tip (white arrow) in expected location.

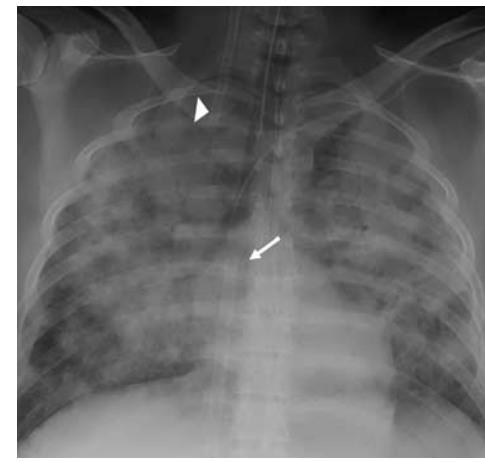

FIGURE 21. Veno-venous (VV) ECMO: frontal radiograph depicting VV-ECMO cannulae in the SVC (white arrowhead) and RA (white arrow) in a patient with respiratory failure due to massive aspiration.

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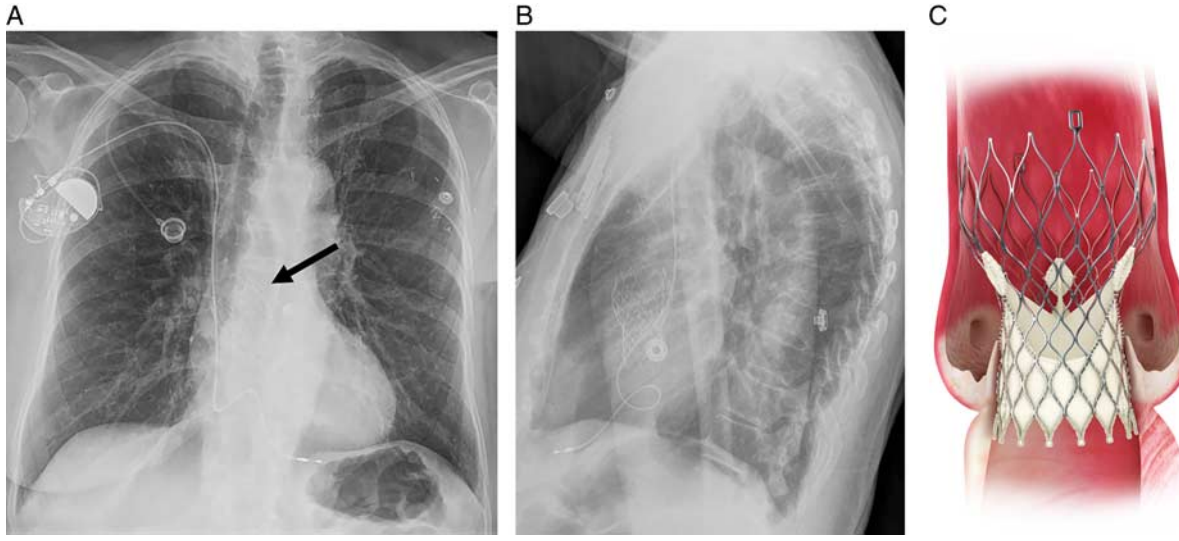

FIGURE 22. CoreValve after transcatheter aortic valve replacement (TAVR): frontal (A) and lateral (B) radiograph in patient after CoreValve TAVR. The valve is goblet shaped and anchors in the proximal tubular ascending aorta, above the sinus of Valsalva (black arrow). CoreValve (used with permission) (C). full color online

patient a redo median sternotomy (Figs. 25, 26). The newly placed transcatheter valve is visible within the original bioprosthetic valve.

Mitral valve repairs are usually performed surgically, but a new option for nonsurgical candidates is mitral valve repair with use of the percutaneously placed MitraClip (Abbott Laboratories, Abbott Park, IL) device.[28,29] The device is placed through a transfemoral approach and positioned to clip together a portion of the anterior and posterior leaflets in order to treat mitral valve regurgitation. Often, >1 clip is needed to achieve this goal. On conventional radiographs, the MitraClip appears as a small rectangular metallic device overlying the mitral valve (Fig. 27).

Percutaneous pulmonic valve implantation was the first nonsurgical valve replacement technique, first described in 2000 by Bonhoeffer et al.[30] It is a treatment option for patients with failing RV to PA conduits, failing native RV outflow tracts, or failing bioprosthetic pulmonic valves resulting in severe right ventricular outflow tract obstruction or severe pulmonic regurgitation. The Melody valve (Medtronic) is a percutaneous pulmonic valve made from a bovine jugular vein valve that is sewn onto a platinum iridium stent. The valve is placed into the pulmonic position via transfemoral venous access and resembles an expanded stent on chest radiograph. Percutaneous pulmonic valve implantation is often used as a nonsurgical bridge while awaiting a permanent solution (Fig. 28).

IMPLANTABLE LOOP RECORDER (ILR)

An ILR is a small cardiac monitoring device that is implanted in the subcutaneous tissues overlying the left pectoralis muscle. The device is rectangular and measures 6.1 cm×1.9 cm×0.8 cm. ILRs are placed in patients with

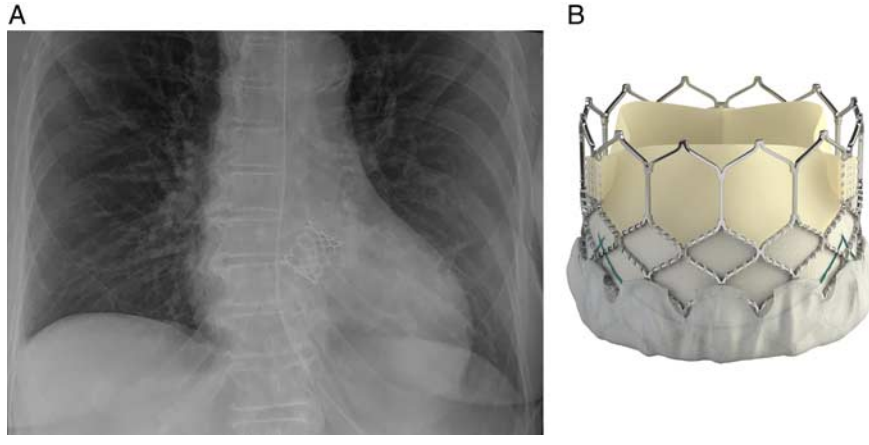

FIGURE 23. Edwards Sapien 3 after transcatheter aortic valve replacement: frontal (A) radiograph after Edwards Sapien 3. Note the different stent cell sizes, which allow for more accurate positioning, because of variable foreshortening of the valve during expansion. Sapien 3 (used with permission) (B). full color online

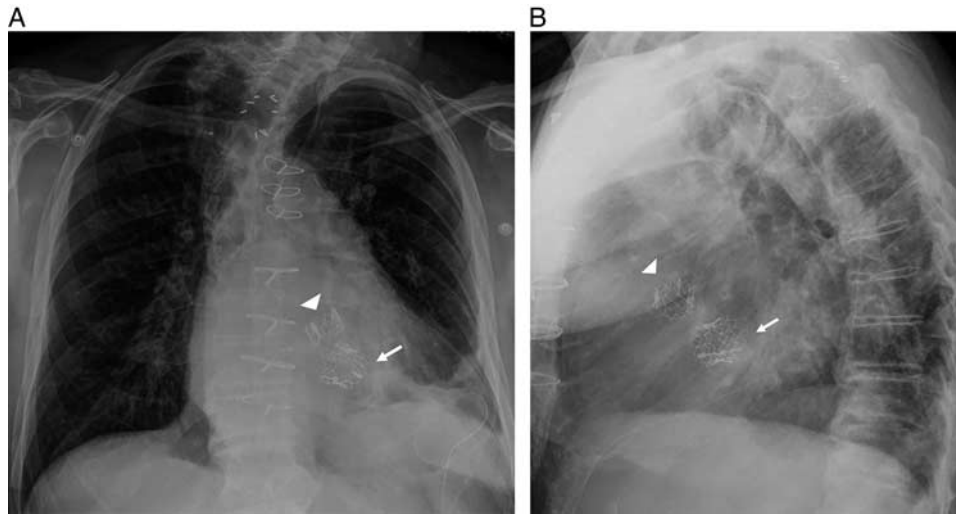

FIGURE 24. After transcatheter aortic valve replacement (TAVR) and transcatheter mitral valve replacement (TMVR): frontal (A) and lateral (B) radiograph after TAVR (white arrowhead) and TMVR (white arrow) with Edwards Sapien valves.

regular symptoms concerning for arrhythmia (such as palpitations or syncope) that are unable to be captured by external telemetry devices, such as a Holter monitor or an external 30-day event monitor. The battery life of an ILR is > 2 years; hence, they can be left in place for a long period of time.[31] On chest radiography, the device appears akin to a portable USB drive and there are no wires or leads attached to it (Fig. 9).

LEFT ATRIAL APPENDAGE (LAA) EXCLUSION DEVICE

LAA exclusion devices are used in patients with long-standing persistent atrial fibrillation (AF) as an alternative to treatment with systemic anticoagulation therapy. The theory behind creation of this device is that intracardiac thrombus in the setting of AF is thought to arise from the LAA. Therefore, if this portion of the heart is incarcerated from the remainder of the heart, then thrombus in this region cannot propagate into the systemic circulation and cause stroke. A study by Blackshear and Odell[32] found that in 91% patients with nonrheumatic AF, left atrial thrombi originated from or were isolated to the LAA. In 2009, Holmes et al[33] published a noninferiority study on LAA exclusion devices compared with standard warfarin therapy for the prevention of stroke in patients with AF. After this point, LAA exclusion devices began being placed more commonly.

The most common method of placement is percutaneous placement or transcatheter deployment of the device. The 3 devices specifically designed for LAA occlusion are the Percutaneous LAA Transcatheter Occlusion (PLAATO, EV3, Plymouth, MN), the Amplatzer Cardiac Plug (AGA Medical, Plymouth, MN), and the Watchman LAA system

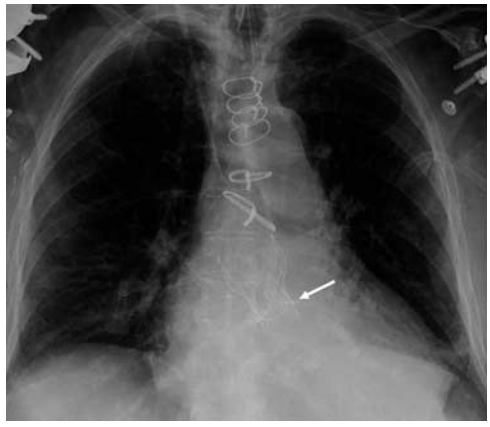

FIGURE 25. Valve-in-valve repair with Corevalve: frontal radiograph of patient with valve-in-valve transcatheter aortic valve replacement after failed bioprosthetic surgical valve (white arrow). Note that the surgical bioprosthetic valve remains in the normal position; the Corevalve is situated within the surgical valve.

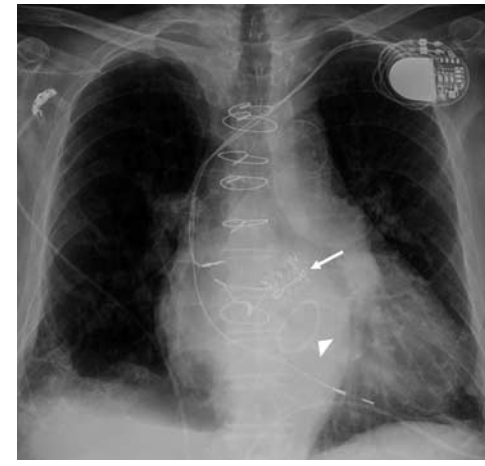

FIGURE 26. Valve-in-valve repair with Sapien 3: frontal radiograph of patient with valve-in-valve transcatheter aortic valve. replacement after failed bioprosthetic surgical valve (white arrow) Note that the surgical bioprosthetic valve remains in the normal position; the Sapien 3 is situated within the surgical valve. A mitral annuloplasty ring is also outlined (white arrowhead).

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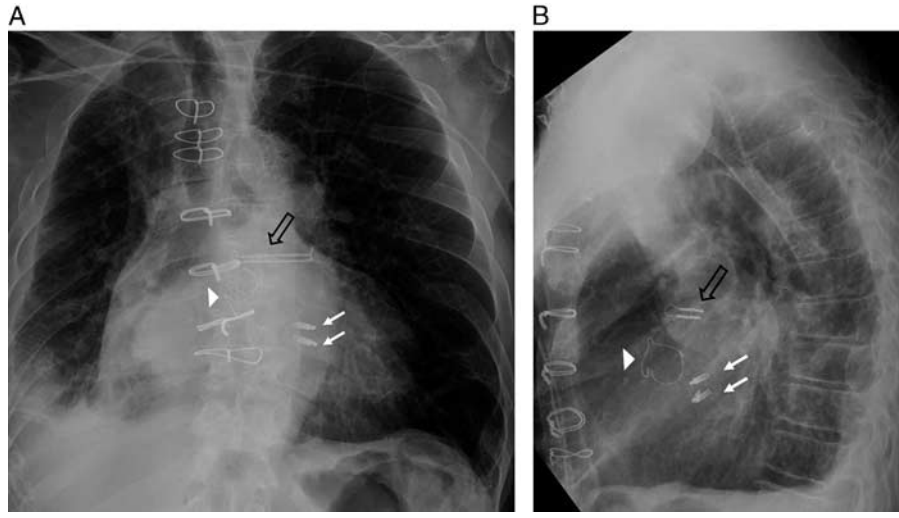

FIGURE 27. Mitral regurgitation repaired with mitral clip: frontal (A) and lateral (B) radiograph after mitral valve repair with 2 MitraClips (white arrows). The patient had prior surgical aortic valve replacement (white arrowhead) and LAA exclusion via AtriClip (open black arrow).

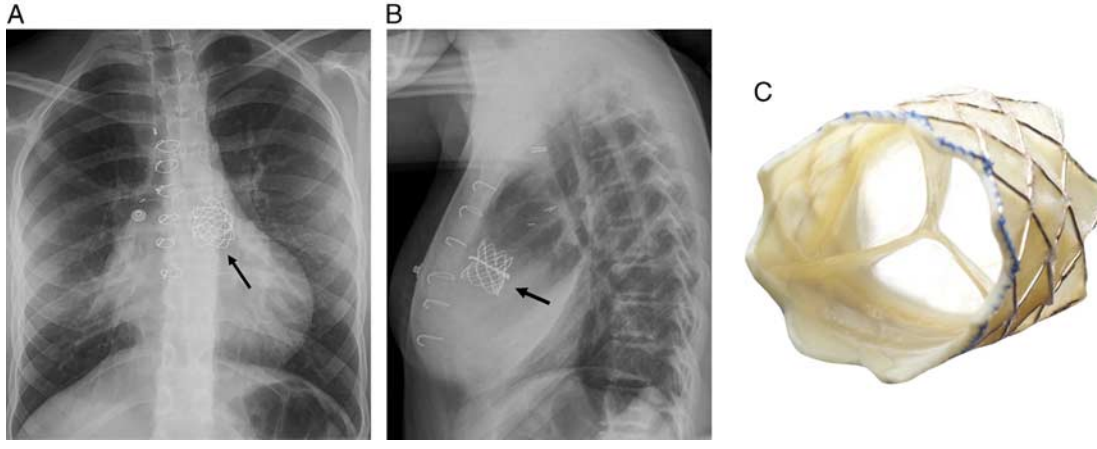

FIGURE 28. Tetralogy of Fallot after pulmonic valve repair with transcatheter Melody valve: frontal (A) and lateral (B) radiograph of patient with history of repaired tetralogy of Fallot with right ventricular outflow tract-PA conduit after Melody valve (black arrow) placement in the pulmonic position. Melody valve (used with permission) (C). full color online

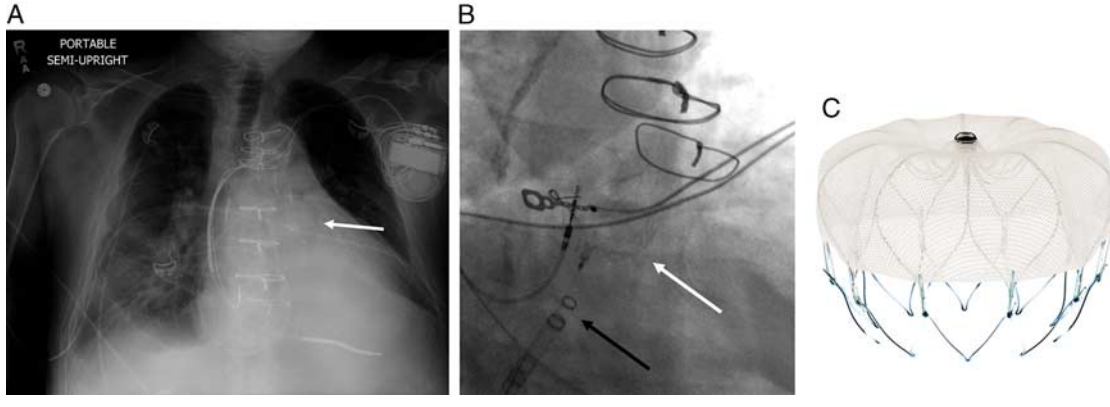

FIGURE 29. Nonsurgical LAA exclusion: frontal radiograph (A) and magnified angiogram view (B) of Watchman LAA occluder device (used with permission) (C). Note the fine metallic mesh umbrella in the expected location of the LAA (white arrow) and the delivery catheter on the magnified angiogram view during placement (black arrow). full color online

(Atritech Inc., Plymouth, MN) (Fig. 29). In general, the device is the shape of an expandable disk, which appears as a rectangular clip on chest radiography. The greatest limitation to use of this device is the high rate of reported incomplete closure ranging from 10% to 80%.[34] Potential complications after placement include atrial tears resulting in hemorrhage and/or pericardial effusion, device embolization, and potential cardiac dysfunction after removal.

The AtriClip (AtriCure, West Chester, OH) is a surgically placed LAA clip, which is used in patients with AF who are undergoing open-heart surgery for other indications (Fig. 27). The clip excludes the LAA, but studies have shown that complete exclusion was not achieved with this device.[35]

CONCLUSIONS

Although this review is by no means an exhaustive summary of all cardiac devices in the chest, it provides an adequate summary of cardiac devices that radiologists are likely to encounter in clinical practice as well as newer forthcoming devices that many radiologists may not yet be aware of. At the very least, familiarizing oneself with the concept and names of these devices can facilitate to an easier online search when the need arises.

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